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H. C. RAMSOWER, *Director*

Vegetable Forcing in Ohio

Plowing soil in a greenhouse in Northern Ohio. The use of labor saving machinery helps to reduce the cost of production

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Vegetable Forcing in Ohio

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Approximately 500 acres of vegetables are forced in Ohio. This type of gardening is the most intensive of all phases of food production. It requires costly equipment and, above all, a thorough knowledge of the methods of creating environments suitable for the growth of the numerous vegetables which are grown under glass structures.

The creation of these environments which approximate subtropical conditions is, moreover, most complicated and difficult. Fertilizers and manures must be used, although the kind and amount often varies with the season of the year and the type of vegetable produced. Heat is usually supplied, but the amount furnished or the method of application is often the cause for a crop failure. Light, water, and fresh air are essential to growth, but the use of inadequate light, water containing toxic substances, or air containing harmful gases are frequent causes for failure. Plants are set close to secure large yields, but not so close that disease is more readily incurred, or that the yield or quality is reduced. Many plants must be pruned and trained in order to utilize the full area above as well as in and on the ground. This pruning and training must be accomplished without undue injury to the plants, and care taken that disease is not transmitted.

Soils must often be sterilized for the control of disease and insect pests. Sterilization modifies the composition of the soil and the effects of these changes should be thoroughly understood. Other diseases and insects must be controlled by the use of resistant varieties, fumigation, spraying, and by sanitary measures. In fact, the business of vegetable gardening is truly a business where skill and knowledge as well as brawn are absolute essentials. It is a profitable business if managed properly, but a costly business if managed poorly.

Location of Greenhouses

The principal objective of the vegetable forcing industry is the production of high quality vegetables out of season. Since quality is so essential to the life of the industry, these vegetables should reach the consumer as soon as possible after harvest. Greenhouses should, therefore, be located near large centers of consumption unless there are very good reasons for locating elsewhere. Land, labor, and coal are large items of expense and should influence the choice of a location. At the same time, the cost of transportation and incidental expenses must not be overlooked if a location at a distance from market is considered. In all instances the quality of the produce should be considered to be of first importance.

In general, it is an advantage to locate near other greenhouses so that associations can be formed. The employees of such associations can grade, pack, and market the vegetables grown by all the members so that a uniform product is insured. Moreover, the necessity for competitive selling and the associated evils of misunderstanding tend to be eliminated if all the produce is sold under one management. Other advantages of cooperative efforts, such as the protection of the individual, the reduced cost of marketing, better advertising, and the extension of the market to new points, can also be better utilized through association activities.

Greenhouses should not be built on soils known to be infested with disease or insect pests. The elimination of these pests is often very difficult and costly.

The condition of the roads, type and fertility of the soil, adequate ventilation, soil and air drainage, water supply, amount of sunlight during the winter, and freedom from excessive smoke and dirt are all factors which should be considered in locating greenhouses (see Fig. 1).

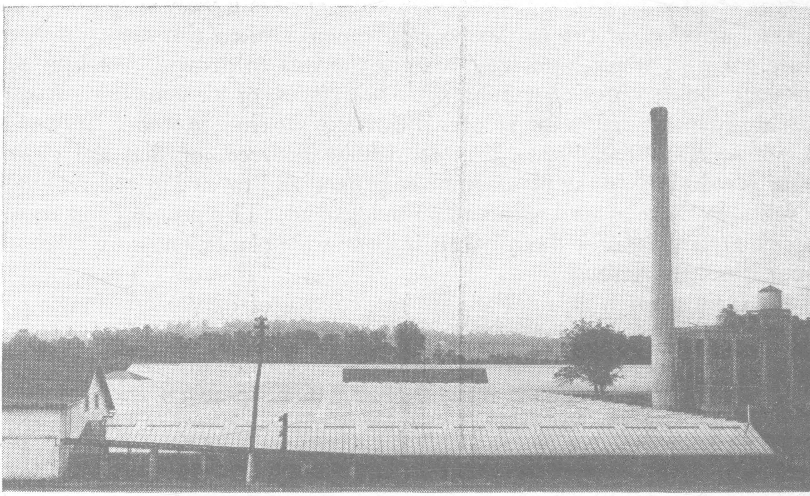

Fig. 1. Greenhouses should be located free from wind breaks so that a good circulation of air can be secured for ventilation at all times.

Type of Greenhouse

Vegetable greenhouses should be strictly utilitarian in purpose. They need not be show houses, and yet they should be constructed so that they admit a maximum of light; so that they can be heated economically and yet be conveniently arranged. Ample head room should be provided for the culture of tall growing crops such as tomatoes and cucumbers. Cost estimates should be based on the average life of the greenhouses rather than the first cost.

Opinions differ widely concerning the best type of greenhouse. In Ohio the greatest number of the houses are of wood or iron frame ridge and furrow construction, and tend toward houses of medium width (20 to 30 feet). This type of construction provides soil beds free from obstructions.

Soils for Greenhouse Crops

Greenhouse crops are grown profitably on a wide range of soil types. Though it is generally thought that cucumbers and melons grow better on lighter types of soils, and tomatoes, lettuce, and spinach produce heavier crops on heavier soils, yet under greenhouse conditions the type is soon so radically changed that its original condition can scarcely be recognized. So for forcing conditions the soil type is not so important, except that extremes should be avoided.

As a rule, it is essential that greenhouse soils be as rich as or even richer than outdoor garden soils. This rule, however, has one important exception, namely, excessive concentration of nitrates during the cold cloudy months is detrimental to crops, especially for tomatoes and cucumbers. In addition the continuous applications of large amounts of fertilizers are likely to produce unfavorable growth conditions which might have been avoided had less been applied. Moreover, it is poor economy to apply costly fertilizers that are not needed or may even be injurious.

Materials Needed for Plant Growth

Carbohydrates

In order to understand soil fertility problems it is essential to know something of what materials are necessary for definite types of plant growth. Practically all green plants require ten or more kinds of plant food materials known to chemists as elements. These elements, combined with one another, are taken up by the plant from the soil and from the air. Thus the air normally contains .03 per cent of a combination of carbon and oxygen known as carbon dioxide (CO_2). This carbon dioxide is taken into the plant through small openings in the leaves known as stomata. These openings are too small to be seen without the aid of a microscope.

Within the plant this carbon dioxide combines with water (H_2O), a compound composed of hydrogen and oxygen. The union of water with carbon dioxide within the plant is possible only by means of energy furnished by light shining on the green coloring material, found in leaves and other plant tissues, known as chlorophyll. The products of this union are many and are classed under the general head of carbohydrates. One of the simplest of these carbohydrates is ordinary sugar (sucrose) consisting of 12 carbon, 22 hydrogen, and 11 oxygen atoms ($C_{12}H_{22}O_{11}$). When sugars combine, more complex carbohydrates are formed such as starches and cellulose. Sugars, starches, cellulose, and related carbohydrates resulting from a union of water and carbon dioxide constitute over 90 per cent of the dry weight of most green plants.

The carbohydrates are the principal constituents of the storage tissues in plants, and also furnish the framework which gives plants a definite shape and resistance to external and internal forces. The quality of most vegetables depends to a large degree upon the relative proportion of carbohydrates (sugars, starches, cellulose, etc.) to free water, and upon the relatively small amount of other elements which come almost entirely from the soil. These elements or combinations of elements include nitrogen, phosphorus, potassium, magnesium, manganese, iron, sodium, calcium, sulfur, chlorine, boron, and perhaps a few others. Of these materials all are found in ample quantities in Ohio greenhouse soils except the first five, and of these nitrogen is the element most often found to be deficient.

Nitrogen

Nitrogen combines with the carbohydrates and minerals to form protein materials. These materials are necessary for the formation of new tissue. The soft, succulent plant parts contain more than the average amount of this protein material, one form of which is commonly called protoplasm. The manufacture of protein materials will go on at night as well as during the day, provided an adequate supply of carbohydrates is available.

Plants which receive full sunlight for normal day periods and which receive little or no nitrogen from the soil are rich in carbohydrates because no nitrogen is available for the formation of protoplasm and new tissue. Such plants are stunted and have light green to yellow colored foliage, a condition indicating nitrogen starvation. This condition may arise during any period in the growth of the plants when nitrogen becomes a limiting factor. It is very common when tomato and cucumber plants have set a good crop of fruits during late spring and early summer months. Such plants fail to set fruits later in spite of adequate pollination until an ample supply of nitrogen has been provided.

Testing Plants for Nitrate Content.—A simple chemical test can be used to determine the nitrate nitrogen content of tissue and soils. To make this test a solution of diphenylamine in chemically pure concentrated sulfuric acid is made by dissolving .05 of a gram of the former in 25 c.c. of the latter. If a deep blue color (cyanine blue) develops on the cut plant tissue when this solution is applied it is safe to assume that the plant is getting ample nitrogen. If, however, no color or only a faint one develops it is fairly safe to assume that the plant is starving for nitrogen.

Testing Soil for Nitrate Content.—The diphenylamine solution can also be used to test the nitrate content of soils. Allow a small amount of nitrogen-free water to slowly percolate through a small quantity (¼ thimbleful) of soil Place one drop of this solution in the circular depression of an artist's slab and add four drops of the diphenylamine solution. A porcelain block designed for making soil acidity tests can be used very satisfactorily for obtaining the soil extract, and an eye dropper pipette is satisfactory for measuring the extract and testing the solution. The color which develops is a quantitative indication of the amount of available nitrates in the soil. A total lack of color indicates no nitrates, and a very dark blue color (cyanine blue) indicates 20 or more parts per million of nitrates; intermediate shades of blue indicate intermediate amounts of nitrates. If the color is intensely deep it will be necessary to dilute the soil extract one or more times in order to get an index of the nitrate content.

The figures for parts per million (p.p.m.) can be converted into pounds per acre by multiplying by two. Greenhouse soils as a rule should contain 20 p.p.m. or more of nitrate nitrogen for the best growth of vegetables, although it is best to have less in the soil (probably 10 p.p.m.) during the dark winter days, especially for tomatoes.

Use Plants Make of Nitrates.—Plants which receive ample light and which are not limited in the amount of nitrogen which they secure from the soil make a good growth which is high in carbohydrates. These carbohydrates combine with the nitrates taken from the soil and this usually results in a maximum crop of fruits.

Plants which receive ample sunlight and a surplus of nitrates from the soil, or plants which are able to manufacture a somewhat limited amount of carbohydrates due to lack of sufficient sunlight, to diseases, or to other factors, make a vegetative and often soft and succulent growth. Such plants may be ideal as leafy vegetables such as lettuce or spinach, but rarely prove of value for the production of a good crop of fruit such as tomatoes, even though blossoms are formed. In fact, the tomato blossoms are likely to drop from such plants without the formation of fruit, even though the blossoms have been pollinated. Such tomato plants show high tests for nitrates or other forms of nitrogenous compounds; the foliage is large and dark green in color.

Plants which are unable to manufacture carbohydrates or only in minute amounts and yet secure an abundance of nitrates become soft, spindling, and soon die. Such plants contain an over-supply of protein or of nitrates.

From the above it is obvious that more nitrogen can and should be applied for large than for small plants, and more nitrogen is usually applied for leafy vegetables than for an equal growth of vegetables from which a crop of fruit is to be harvested. Under ordinary conditions the nitrate content of greenhouse soils should vary between 20 and 40 p.p.m. during clear bright weather, and be somewhat less than 20 p.p.m. during cloudy weather.

Nitrogen Carriers to Apply.—Nitrogen should be applied before starvation symptoms appear, if possible. For acid soils use sodium or calcium nitrate and for alkaline soils use sulfate of ammonia, urea, or leunasaltpeter. Surface applications should usually be made at the rate of from 100 to 300 pounds per acre as often as necessary. During bright weather it may be necessary to make the applications at weekly intervals.

Phosphorus and Potassium

Greenhouse soils usually supply ample phosphorus and potassium for forced vegetables. It is, however, usually wise to make annual applications of a fertilizer containing 12 per cent of phosphoric acid and 12 per cent of potash at the rate of 1000 pounds per acre. This fertilizer should be worked into the soil to a depth of three to four inches, as it does not dissolve and leach downward into the soil as do nitrogen fertilizers.

Plants that are lacking in phosphorus are usually stunted but dark green in color. Plants making an unsatisfactory growth due to the lack of potash usually have brittle stems and the lower leaves become spotted, then shrivel and die, but often remain attached to the plants. Plant and soil tests can be made which indicate phosphorus and potassium starvation. Directions for making these slightly complicated tests can be secured upon request, or samples of soil may be submitted through your county agricultural agent or sent direct to the Soils Department of the Ohio State University.

Carriers of Phosphorus and Potash.—Phosphorus is usually supplied as superphosphate, and potash as the muriate or sulfate of potash or in a mixed fertilizer such as an 0-14-6 or an 0-12-12.

Manganese and Magnesium

Manganese.—Manganese occasionally becomes a limiting plant food material in greenhouse soils. It is needed most frequently on soils which are neutral or alkaline in reaction, due to the fact that this element is rendered less soluble or available by alkaline conditions. An application of 100 pounds per acre of manganese sulfate is usually effective. Manganese deficiencies in plants are indicated by chlorotic foliage, that is, whitish or yellowish leaves, but the veins usually remain dark in color.

Magnesium.—Symptoms of magnesium deficiencies are shown by bleached leaves due to the destruction of the green and yellow leaf pigments. The older leaves are affected first. The lack of magnesium does not, however, cause a spotting of the leaves as is the case in potassium starvation. Magnesium fertilization is needed still less frequently than manganese fertilization. Magnesium deficiencies may be relieved by the addition of 20 to 30 pounds of magnesium oxide per acre.

Most fertilizers, including manure, contain considerable magnesium and manganese and it is, therefore, seldom necessary to make separate applications of these materials.

The other mineral plant food materials taken from the soil are rarely lacking in greenhouse soils.

The Value of Animal Manures

Animal manures contain a small amount of nitrogen, phosphorus, and potassium, as well as most of the other plant food materials. Moreover, they liberate carbon dioxide, and their value in this capacity may be much greater than is now realized. Animal manures also improve the physical condition of the soil.

Organic materials, such as manures and vegetable and animal refuse, are used as bases of plant food supply. They are also needed in greenhouse soils to support the growth of bacteria and molds, which in turn liberate the plant food materials that are later taken up by the plants and used in growth. In order to be the most effective in supporting a normal plant life, the carbohydrate portion of organic materials should have a ratio of about 10 parts carbon to 1 of nitrate. The carbohydrate portions furnish the energy for the bacteria and molds so that they may live, grow, and do the work of breaking down the protein material.

The addition of fresh or partially rotted manure as a mulch does not, however, immediately add nitrogen which is available for plant growth. As a matter of fact, the minute bacteria living in the decaying manure utilize or absorb part of the available nitrogen already in the soil, so that the plants are unable to secure an adequate supply. The nitrate nitrogen content of decaying manure mulches, or soils under manure mulches, can easily be determined by the diphenylamine test. In most instances it shows less than 10 p.p.m., an amount far too small for the growth of vegetables during most seasons of the year. When the manure is thoroughly decomposed the nitrate nitrogen content is much higher. Manure should, therefore, be applied preceding the fall crop, so that it will reduce the nitrate supply during the late fall and winter; by the following spring, the organic material will be thoroughly decomposed (with a resulting increase in the nitrate nitrogen content), in time to liberate a nitrate supply when it is most needed.

Many greenhouse men are incurring much unnecessary expense by the use of excessive amounts of manure. An application of 40 tons of well rotted manure per acre each year is ample.

Soil Acidity

Soil acidity or alkalinity in itself has far less influence on crop growth in the greenhouse than is generally thought. Many fertilizers are, however, made more or less soluble by the soil reaction. In some instances the fertilizers are leached away after they have been made available; in other instances they dissolve so slowly that they are unavailable for plant growth. The effects of varying degrees of acidity are also influenced or buffered by the presence of organic matter and by many other soil constituents, including colloids and many chemical constituents formed in some soils. Contrary to the common belief, most vegetables grow better in a slightly acid rather than a neutral or alkaline soil.

The acidity of soil is best indicated by the concentration of hydrogen ions (or ions giving equivalent effects) which it contains. The concentration of these ions is indicated by the symbol *p*H. Soils that have a hydrogen ion concentration of a value of 7 *p*H are known as neutral, those with a *p*H value above 7 are alkaline, and those with a *p*H value below 7 are acid. The lower the numerical value of the *p*H the greater the hydrogen ion concentration becomes. For instance, a soil having a *p*H value of six is ten times as acid as a soil having a *p*H value of seven.

Most vegetables make a satisfactory growth if the acidity lies between the values *p*H 6 to *p*H 7, and little difficulty is experienced if the values fluctuate between *p*H 5.5 and 7.5. Above *p*H 7.5, however, the plants often become chlorotic. This may be due to lack of maganese, magnesium, iron, or to other factors. Potassium starvation symptoms also frequently occur on alkaline soils. When the soils are very acid, that is, below *p*H 5.5, injury may result from lack of phosphorus or calcium, or be due directly to acidity of the soil.

The *p*H values of greenhouse soils can be determined very easily by means of indicators such as bromthymol blue, chlorphenol red, bromcresol green, and phenol red.*

If the soil is found to be too acid it can be corrected by the addition of finely ground limestone. Under greenhouse conditions in Ohio, however, the addition of liming material such as finely pulverized limestone or hydrated lime is rarely necessary. This is due to the fact that the water used for irrigation in most parts of the state contains alkaline soluble salts, which constantly tend to make the soils more alkaline and, therefore, less acid. Moreover, the residues left from the applications of animal manures and commercial fertilizers frequently leave the soil more alkaline.

If the soils become too alkaline—that is, show a *p*H value of above 7.5, the reaction value can be lowered by adding flowers of sulfur or aluminum sulfate.

Soluble Salts

Soluble compounds in soils are classed collectively as soluble salts. They may be fertilizers such as sodium or calcium nitrate, or muriate or sulfate of potash. They may also be ordinary table salt, or sodium carbonate or sodium sulfate, none of which has fertilizer value except under unusual conditions. Some salts may be neutral, some acid, and some alkaline. If, however, the aggregate concentration of all salts becomes greater than .26 of 1 per cent there is considerable danger that the crops will be injured.

An excessive accumulation of a whitish brown or yellow crust on the surface of dry soil is a sure indication that there is danger from excessive salts. These salts are added to soils in fertilizers, in animal manures, and in irrigation water. Obviously, it is essential to use all of these materials, but an excessive use of any of them is not only costly but may eventually render the soil toxic for plant growth. It is frequently necessary to change the water supply, because some waters contain an excessive amount of soluble salts. Water which contains more than 250 to 300 parts per million (p.p.m.) of soluble salts should not be used if other water can be secured.

The injury from soluble salts is due to the fact that the salts cause the plants to wilt, a process known technically as exosmosis. These salts move up and down in the soil as water is evaporated from or is added to it. However, they cannot be taken up by the air above the soil as is water, consequently they accumulate at the surface of the soil when the soil becomes dry. During this period the plant roots in the surface soils become injured. Had the salts been kept uniformly distributed throughout the soil no such injury would have resulted; in fact, the soil in this condition might be in its maximum state of productivity. If, however, salts continue to accumulate, there comes a time when the injury cannot be eliminated even by their uniform distribution.

Applications of animal manures to such soils may afford temporary relief because some of the salts are withdrawn from the solution by a process known

* These indicators, with equipment and instructions included, can be purchased at most drug stores. A very simple test kit with complete instructions for its use can be purchased from the Soils Department at The Ohio State University.

to chemists as adsorption. This relief is, however, only temporary. The obvious remedy is to remove the excessive salts. This may be accomplished by scraping off the surface of the soil after the salts have accumulated thereon by excessive drying. The other method is to apply large amounts of fresh water so that the salts are leached away—that is, washed out through tile drains. It is important to be sure that the water is actually carried off through tile drains. No value can result if the salts are merely washed several feet down in the soil, as they will return to the surface of the soil as soon as the water is taken up by the plants or is lost by evaporation.

Since plant food material is also removed with the soluble salts it may be necessary to add more, especially nitrogen fertilizers, following the removal of soluble salts.

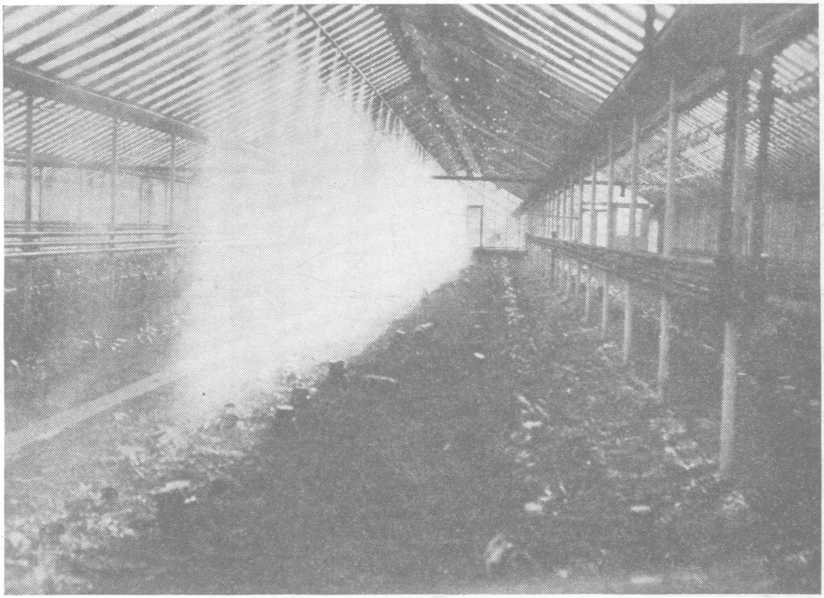

Fig. 2. Watering cucumbers with an overhead system.

Suggestions for Watering Plants

The need for water for the growth of plants is so well recognized that it is often applied year after year without much thought until plants no longer grow. At this time careful studies often reveal the fact that the water contained dissolved compounds which, when they accumulated during a period of years, proved injurious to plants. The source of water should be carefully investigated to make sure that it does not contain excessive amounts of soluble salts or other injurious compounds. It should not contain much in excess of 250 to 300 p.p.m. of dissolved salts. Chlorine, which is often used to purify city water supplies, is especially injurious. All greenhouse soil in solid beds should be provided with tile drainage so that undesirable soluble compounds can be leached away if necessary. Foliage should be kept dry, especially at night.

Experiments have proved that warm water is of no special value for watering plants and may in some instances prove injurious. If, however, the force of the water is to be broken by means of the thumb or finger on the end of a hose it is essential that the chill be reduced slightly for the comfort of the operator. Ice cold water should not be used.

As a rule, water should be applied in the morning after the temperature starts to rise and preferably when the sun is shining. During dark cloudy weather it is very important that the foliage of the plants be kept as dry as possible in order to avoid the spread of diseases. During the warmer seasons it may be necessary to water two or three times per day. During the early growth of some crops such as tomatoes it is necessary to keep them cool and dry in order to insure a maximum set of fruit. In some cases it may not be necessary to water for periods of three or more weeks. Plants should rarely be allowed to wilt.

Water is usually applied by overhead systems in large ranges (see Fig. 2). If such systems are carefully adjusted little or no hand watering will be necessary. For smaller ranges the familiar hose is used for conveying the water to the plants. Subirrigation is occasionally used. Theoretically, subirrigation has many advantages but practically it is used but little. Tile used for sterilizing the soil may also be used for conveying water for subirrigation if the subsoil is fairly impervious to water. The tile lines must not have a slope of more than one to two inches per 100 feet.

Fig. 3. Water supplied in trenches helps to keep plant foliage dry and thus reduces the spread of diseases.

During dark cloudy weather water is often applied in trenches (see Fig. 3) in order to keep the foliage dry and thus reduce the chance of disease spread.

The syringing of plant foliage for the control of red spider and other pests should be done frequently and thoroughly during clear weather so that the operation can be discontinued when the cloudy season arrives.

Ventilation in the Greenhouse

Ventilation is essential in order to maintain the proper degree of moisture in the air and to furnish a fresh supply of carbon dioxide and oxygen for the plants. It is also an aid in regulating temperatures. Though it is possible to create, in the greenhouses, an atmosphere which is better than the average atmosphere on the outside, it is also possible through a very slight amount of neglect to cause untold damage if the atmospheric conditions are allowed to become especially bad for a period of a few days or even a few hours.

Regulating the Moisture Content of the Air.—The regulation of the relative humidity (moisture content) of the air is doubtless the most important

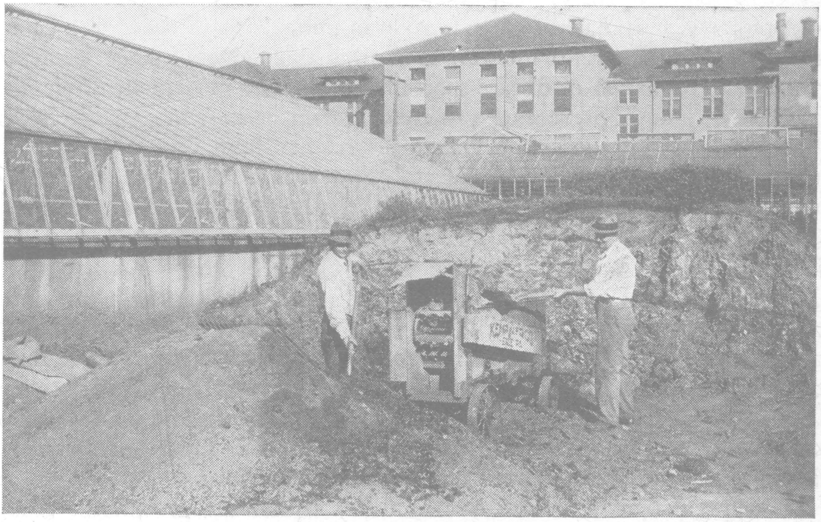

Fig. 4. Forced vegetables should be given ample ventilation. This is especially true of the fall crop of tomatoes, as it helps to control tomato leaf mold. Use both side and top ventilators as illustrated. Heat should also be provided to assist in the circulation and distribution of air.

Soil grinders similar to the one shown above are useful in preparing soils for seed and seedlings.

function of ventilation. It is known that disease spores are very likely to germinate and grow if the relative humidity of the air rises above 90 per cent. Low humidities are less to be feared than high humidities. A relative humidity of about 70 per cent is generally considered best.

The moisture content of the air can be measured by a sling psychrometer, by a hygrodeik, or by a hair hygrometer. Correct readings may be secured by means of the accurate sling psychrometer. The hair hygrometer may be connected with a clock and self recording instrument so that a continuous record can be secured. It must be calibrated frequently. It is also possible to connect these self recording instruments with automatic temperature regulating and ventilation devices, so that the proper humidity can be controlled automatically.

One fundamental principle to be remembered in the regulation of the humidity is that the moisture content of any air is lowered if it is heated to higher temperatures. During the winter, when the outside temperature is much colder than that in the inside, there is little danger that the inside relative humidity will go above 90 per cent, because cold air is continually finding its way into the greenhouse, where its water vapor content is lowered below the danger point. The greatest danger from excessive moisture in the air is experienced in the fall, when there is scarcely any difference between the outside and inside temperatures. During cloudy weather, or when the atmosphere on the outside is full of moisture, it is a good plan to heat the greenhouses even though the temperature is raised higher than that which the plants ordinarily require (heat is most essential from 2 to 7 A. M.). At this season of the year is may also be advisable to utilize fans in order to facilitate the changing of the air. If moisture is allowed to condense on the plants, an increase in germination of disease spores follows. The movement of air is of considerable value in preventing this condensation of moisture on the leaves, although it may not appreciably lower the relative humidity. It is claimed, however, that disease spores are able to germinate, even though there is no moisture condensation on the leaves, if the relative humidity rises much above 90 per cent.

The value of forced ventilation is questioned by many commercial as well as technical workers. If fans are used it is important that excessive drafts be avoided. Excessively cold or hot air should likewise be avoided. Some growers advocate the forcing of air into the houses, while others force it out and allow the fresh supply to enter the house through the ventilators and cracks in the glass. Theoretically, both methods have merits and disadvantages. Some forced ventilation systems can be used for the rapid distribution of insecticides or fungicides in either the dust or gaseous forms.

The regulation of the relative humidity within the greenhouse is also a problem during the spring and early summer, although not so much of a problem as during the fall because of the increased sunlight and lower outdoor moisture content.

Give Plants Fresh Carbon Dioxide and Oxygen.—Ventilation during the day for fresh supplies of carbon dioxide and during the night for fresh supplies of oxygen is a problem which has received but little attention. It is known, however, that these materials are needed, and it is a wise plan to provide some ventilation at all times even though the humidity problem is not involved.

Ventilation Helps to Control Temperature.—Of course, ventilation should be provided in an effort to keep the inside temperatures from rising too high above the optimum temperatures for the crops. Drafts during hot weather are not injurious, except on cucumbers and muskmelons, and help to cool the plants because they induce a greater amount of evaporation, which is a cooling process. During cold weather, care should be used to avoid any greater loss of heat through the ventilators than is necessary to maintain a change of air sufficient to keep the relative humidity lowered to the proper point.

The type of furnace which should be used to heat greenhouses is without the scope of this bulletin. From the heating standpoint most growers agree that the hot-water system is better for small ranges and steam is generally better for large ranges. The use of self stokers, pumps to force the circulation of water, vacuum heating units, and other heating appliances and attachments has made it possible to use hot water or steam almost equally well for large or small houses. One of the most important items of expense involved in operating greenhouses is the cost of fuel and the operating of the heating units. It is, therefore, highly important to make use of effective heating units which are equipped with economical labor saving devices. From the standpoint of soil sterilization it is highly important to have adequate steam boilers available for this work, as sooner or later it is apt to become an essential part of the greenhouse operations.

Optimum Temperature Gives Maximum Yield.—Years of practice and experience have been used as a basis for regulating the temperatures for the different crops. In spite of this, very little definite information is available concerning the correct temperatures for plants growing during different kinds of weather and during different stages of maturity. We do know, however, that the process known as respiration goes on at a much more rapid rate at high than at low temperatures. In fact, this process is accelerated from two to three times for each 18° F. rise in temperature. Since respiration is a tearing down (actually slow burning) of the tissues, it is essential that excessive temperatures should not be used. This is true especially if the opposite process known as photosynthesis (or the manufacture of plant materials) is going on at a slow rate due to lack of sufficient light, to a deficiency of carbon dioxide, or to other causes.

The optimum temperature for photosynthetic activity is not accurately known. It no doubt varies with the different plants, but for most forced vegetables the optimum photosynthetic temperature is assumed to be from 60 to 70° F. Above these temperatures the process of photosynthesis is slowed down, rather than accelerated as is the case with the respiration process. Though respiration is essential in furnishing heat energy for plant reactions, it is obviously important that the process must not go on too rapidly. The regulation of this process is accomplished under practical conditions by the lowering of the temperatures in the greenhouses during the night, and during cloudy weather when the food manufacturing process (photosynthesis) ceases or is proceeding slowly.

Table 1 gives the temperatures generally assumed to be correct for the commonly forced vegetables. If cloudy weather persists for long periods the temperatures should be lowered a few degrees below those recommended in the table. Obviously it is impossible to keep the greenhouse temperatures lower than outside temperatures. Shading the plants may help slightly. High temperatures are, however, not so injurious when the sun is shining, as food manufacture is also proceeding at a rapid rate at such times.

Table 1. Temperatures Considered Best for Forced Vegetables

Vegetable	Day Temperature		Night Temperature
	Clear	Cloudy	
Asparagus	65-70	55-60	50
Beans	80	65-70	60
Beets	65	55-60	50
Carrots	65	55-60	50
Cauliflower	65	55-60	50
Celery	65	55-60	50
Cucumbers	85	75-80	65
Dandelion	60	50-55	45
Lettuce	60	50-55	45
Mint	60	50-55	45
Muskmelons	85	75-80	65
Mustard	60	50-55	45
New Zealand Spinach	75	60-65	55
Parsley	60	50-55	45
Radishes	60	50-55	45
Rhubarb	65	55-60	50
Spinach	60	50-55	45
Tomatoes	70-75	60-65	55-58
Water Cress	60	50-55	45
Witloof Chicory	65	55-60	50

In arranging the heating coils in a greenhouse it is essential to remember that heat rises. Heating coils located several feet above the growing plants are ineffective. One of the great advantages of the narrow ridge and furrow house is that heating coils can be installed near the soil under each row of gutter posts, thus insuring an even distribution of heat and an adequate air movement, including ventilation.

Relation of Light to Plants

All life is dependent upon the manufacture of food by living green plants, and this process cannot go on in the absence of light. Furthermore, a definite amount and kind of light is necessary in order to furnish the energy for plant food manufacture. The standard of measurement of light intensity is a "foot-candle," which is the amount of illumination produced by a standard candle at a distance of one foot.

Maximum Growth Dependent on Degree of Light.—Experimental tests have provided a fairly reliable index of the best amount and kind of light. Most forced vegetables grow best when they are exposed to a light intensity of from 1000 to 4000 foot-candles, and it is likely that an intensity of 2000 foot-candles would suffice under ordinary conditions. Leafy vegetables seem to require somewhat less than vegetables which must produce fruit as well as foliage.

Plants growing on the outside in Ohio during the clear days of June frequently receive an intensity of over 10,000 foot-candles. This is obviously more than they need. Plants growing in greenhouses during the cloudy weather of December and January frequently receive less than 100 foot-candles light intensity and occasionally receive as little as 10 foot-candles light intensity. (It requires a light intensity of 7 foot-candles in order to read without undue eye strain.) The lack of light is, therefore, the chief limiting plant growth factor in Ohio during December, January, and a part of February.

Every possible effort should be exercised in order to supply the plants with light during this time. If the greenhouse glass is dirty it should be cleaned, as dirty glass cuts off a high percentage of light. A solution of oxalic acid and water or a good commercial cleaning solution can be applied to the glass and washed off with clear water. The greenhouse structural parts should be painted white so that they will reflect the light to the plants rather than absorb it.

Can Artificial Light be Utilized?—The use of artificial light has not been used on a commercial scale although plants have been grown repeatedly by the use of artificial light alone. It is doubtful if commercial growers can afford to pay more than two cents per kilowatt hour for electricity considering the present prices of forced vegetables. When electricity is used as a source of light it is essential that adequate reflectors be used in order to prevent the dissipation of light away from the plants. Provision should also be made to make use of the heat liberated for warming the greenhouses. If a greater part of the energy of electricity could be converted into light rather than heat there is little doubt but that its use in lighting vegetable forcing structures would be utilized to a considerable extent.

For a discussion on the use of artificial light in connection with artificially generated carbon dioxide, see page 18.

Quality of Light Most Effective for Plant Growth.—The kind or quality of light is also important. The quality of light is commonly measured by the length of waves produced by the light. The symbol $\mu\mu$ indicates one-millionth of a millimeter. It is possible to see light which produces wave lengths varying from 390 to 770 $\mu\mu$. Beyond these extremes light waves are produced but they are not visible to the eye. All light rays from 390 to 680 $\mu\mu$ are effective in photosynthesis. Rays longer than 680 $\mu\mu$ do not seem to be effective; those 675 to 680 $\mu\mu$ are most effective, and rays ranging from 390 to 675 $\mu\mu$ seem to vary in their effectiveness in proportion to the energy which they furnish. The red yellow (orange) light rays are approximately 675 $\mu\mu$ in length, and they are very likely the most effective because they bear the complementary of the green color of the leaves and are, therefore, absorbed and utilized to a greater extent than are the rays producing other colors.

Short light wave lengths known as ultra violet rays are commonly thought to be effective in modifying the shape and structure of plant parts, although there is considerable doubt concerning this and other claims made for them. As a matter of fact, very few ultra violet rays enter ordinary greenhouses and yet the plants produced are apparently normal provided the intensity of the longer light rays is adequate. Greenhouse grown plants are known to contain the usual supply of vitamins A and C.

Glass Values Vary.—Many claims have been made for various kinds of glass. Although their values cannot be determined without experimental tests it seems reasonable to expect the most from those kinds of glass which allow the greatest proportion of the rays from 390 to 680 $\mu\mu$ to pass through. In general, glass containing relatively less lead and more silicon are considered best.

Increasing the Carbon Dioxide in Air

Reference has already been made to the necessity for carbon dioxide. The yield of forced vegetables has been increased by increasing the carbon dioxide content of the air from .03 per cent (normal amount) to .3 per cent. It is said that the gas is generated in many greenhouses in Germany by burning a form of coke called O. C. O. bricquettes. Increases in plant growth amounting to 20 to 30 per cent have frequently been reported, but not verified in the case of tomatoes and cucumbers.

Light Becomes the Limiting Factor.—The gas generated in various ways has been used from time to time in America but has never assumed commercial importance. This is probably due to the fact that light rather than carbon dioxide is the first limiting factor in plant growth during the period when growth is most noticeably limited. As a matter of fact, light is essential for the utilization of carbon dioxide, and little use can be made of the artificially generated gas except on days when the sun is shining. If artificial light becomes generally used in this country it is very likely that artificially supplied carbon dioxide will also be used. With ample sunlight it is now thought that added carbon dioxide will hasten the maturity of greenhouse crops.

If artificial light is used, care must be taken not to expose plants to light periods which will cause them to change their fruiting habits. For instance, witloof chicory, beets, mustard, radishes, and spinach will go to seed if subjected to illumination for more than 12-hour periods, but will continue a vegetative growth if they receive light during periods of less (approximately) than 12 hours. The duration of the light period may have pronounced effects on some of the other forced vegetables.

Planting Distances

Plants producing dense foliage should be planted farther apart during the fall than during the spring months. This is to provide better ventilation for the control of diseases, and so that better use can be made of the scant supply of sunlight. The planting distances recommended in Table 2 are those proved by experiments to be most effective, although additional research is needed to determine the best planting distances for most vegetables.

Table 2.—Planting Distances for Forced Vegetables.

Vegetable	Distance Between Rows in Inches	Distance Between Plants in the Row (Inches)
Asparagus	*	*
Beans	18	2–3
Beets	10–12	2–3
Carrots	6	1–2
Cauliflower	16–18	14–16
Celery	6–7	6–7
Cucumbers	42–52	16–22
Dandelion	6–8	4–6
Lettuce	8–9	8–9
Mint	6	6
Muskmelon	42–52	15–18
Mustard	6–8	6–8
N. Z. Spinach	12	12
Parsley	8–10	8–10
Radishes	4–6	1–1½
Rhubarb	*	*
Spinach	8–10	½–1
Tomatoes	32–42	14–18
Water Cress	4	4
Witloof Chicory	3–6	3–6

Beans, carrots, mustard, radishes, spinach, and often beet seeds are usually planted in place, though the seeds of cauliflower, cucumbers, celery, dandelion, lettuce, muskmelons, New Zealand spinach, parsley, and tomatoes are usually planted in sterilized soil in flats. The seedlings of these latter crops are usually transplanted once before they are set in the greenhouse soil. The roots for forced asparagus, rhubarb, chicory, and sometimes beets are grown in the field and then transplanted to the forcing bed. Asparagus, rhubarb, and chicory are usually forced in darkened buildings. Chicory roots are generally set close together in sand and soil, thoroughly watered, and then covered with six to eight inches of sand in order to secure compact blanched shoots or heads. Water cress is propagated from seed and cuttings.

Time to Plant

The time required to grow crops to edible maturity varies greatly with the season of the year. Lettuce, cauliflower, cucumber, and melon seed are usually sown four to six weeks, and celery and tomatoes eight to ten weeks before the plants are needed for the permanent planting. Leaf lettuce, ordinary spinach, and radishes grow to a marketable size in from four to eight weeks after the plants or seed are planted in the greenhouse soil. Asparagus, beans, beets, carrots, cauliflower, celery, mustard, rhubarb, and witloof chicory require a somewhat longer time (six to fourteen weeks) and cucumbers, melons and tomatoes a still longer time for the maturity of a satisfactory

* Plant as close as possible without breaking fleshy roots.

crop. New Zealand spinach, parsley and water cress will continue to produce as long as favorable growing conditions are provided.

Most Ohio growers plan to have their houses planted by August 15 to 30, although some of the quick growing cool season crops are likely to mature at the same time as outdoor crops if they are planted too early. The earlier planting dates are recommended for the northern sections of the state because of the poor light conditions in the lake region after the beginning of November. Of course it will be necessary to plant the seed of plants to be transplanted before this date. The planting dates of succeeding crops will depend on the condition of the crops first planted and on the time required for the later crops to reach the transplanting size if they are to be transplanted.

Fig. 5. Cauliflower in the greenhouse after an intercrop of lettuce has been harvested. The lettuce was harvested before the cauliflower plants were unduly crowded.

Intercropping

Intercropping refers to the practice of growing two or more vegetable crops on the same area at the same time. Crops requiring different lengths of time to mature are usually used, such as lettuce or parsley between tomatoes. This allows one crop to mature and be harvested before seriously interfering with any of the cultural practices needed to successfully mature the crop occupying the ground for the longer period of time.

As a general practice intercropping is not recommended. Different vegetables require different cultural methods and climatic conditions. Therefore, one crop is grown to the detriment of the other. The price received for the intercrop rarely makes up for the decrease in yield of the main crop, and often barely pays for the labor of planting and harvesting of the intercrop.

Parsley Intercropped with Tomatoes Was Profitable.—There are, however, exceptions to this rule, and at times and in certain localities enough money is received for the intercrop to bear the expense of both crops, leaving the second crop as profit. Such was the case of the parsley between tomatoes in Figure 6, while lettuce intercropped with tomatoes in the same range barely paid expenses, and the first fruit cluster and in some cases the second cluster was lost, due to the presence of the lettuce. The practicability of intercropping will have to be determined by the grower and will be influenced by his own local market and his system of handling crops in his houses.

Fig. 6. Tomatoes intercropped with parsley.

Some Vegetables used as Intercrops.—

Lettuce or mustard between tomatoes, cucumbers, cauliflower, or melons (see Fig. 5).

Parsley between tomatoes, cucumbers, melons or cauliflower.

Beets or carrots between tomatoes, cucumbers, melons or cauliflower.

Spinach between tomatoes, cucumbers, melons or cauliflower.

Beets, carrots, mustard, parsley and spinach are usually seeded between the major crop.

The lettuce is transplanted from the seed bed to the forcing bed and is usually planted at the same time the major crop is planted.

Whole stored beets are sometimes set between the major crop and forced for tops.

Parsley roots are sometimes planted instead of seed as an intercrop.

In tomatoes the intercrop may be planted in every other row, leaving room for workmen to get through to prune and pollinate the flowers.

Lettuce, radishes, cauliflower, and spinach do not require pollination unless a crop of seed is raised. Beans require no special treatment for the set of a good crop. Cucumbers, muskmelons, and tomatoes, on the other hand, require pollination although tomatoes, especially the English varieties, will set a good crop during clear weather without pollination.

Fig. 7. Pollination by the finger method is effective even during cloudy weather. If plants are supported by stakes the flowers can be pollinated during clear weather by tapping the stakes. Many stakes can be shaken simultaneously if they are connected from above with a wire network.

Cucumbers and muskmelons as a rule have male and female parts in different flowers, and it is necessary to bring the pollen from the male flower to the stigmatic surface of the female flower to effect pollination. The female flower can readily be distinguished by the small cucumber or melon at the base. Although hand pollination of muskmelons and cucumbers is possible, it is a tedious and expensive operation and bees are generally used. The hives and bees are brought into the house when it is desired to start the pollination work. Water and bee food must be provided. Sometimes the hives are placed near the wall of the greenhouse so that the bees can have an inside as well as outside entrance during mild or hot weather. The hives should not be left in the houses longer than necessary. The Geneva variety of cucumber sets some fruits without pollination.

Tomatoes require little artificial pollination during the late spring or summer. During bright days of fall or winter it often is sufficient to jar the plant by tapping the plant or the stake to which it is attached with a well padded stick. During cloudy weather it is, however, necessary to take more precautions, especially with certain varieties. The tapping method is the one generally used during this period. By tapping the flowers so that the stigma is forced gently against the pollen shed on the finger tip (see Fig. 7) this method is doubly effective.

An electric pollinator has recently been patented which is fairly satisfactory for tapping the flowers.

Pruning for Maximum Yields

Fig. 8. The side shoots should be removed from tomatoes while they are small. Care must be taken to avoid the transfer of sap from plant to plant.

As a rule, pruning is a checking process and is to be considered as a necessary evil. It is, however, necessary to train the tomatoes, cucumbers, and muskmelons in order to utilize the area in the greenhouse above as well as on the ground.

Moreover, the set of fruit on the main stem of these plants, especially tomatoes, is generally better than the set on the laterals. Thus it is important to plant a relatively large number of plants per given area rather than to allow a fewer number to spread out and occupy the same area. In inducing the tomatoes, cucumbers, and muskmelons to grow in any definite manner, it is important to remove the undesired parts as soon as they are formed. If this is done the growing points will merely be diverted, and no great amount of plant food manufacturing areas will be removed as will be the case if large branches and leaves are removed.

Careless Pruning May Cause Infection of Plants.—It is also essential that no sap be transferred from plant to plant during the pruning process, so that the danger from spreading virus diseases such as mosaic will be reduced to a minimum. This can be easily accomplished while the plant parts are small and brittle by grasping the part to be removed between the thumb and index finger and giving it a quick sideward jerk. If this is done carefully the hand need not come in contact with the part of the plant left intact. Figure 8 shows the correct method of pruning tomatoes.

The removal of the foliage from forced vegetables is seldom profitable. The removal of badly diseased foliage is questionable even though it has ceased to function in photosynthesis, as the unnecessary shaking of the plants serves to shake the disease spores on to the surrounding healthy plant parts. Large tomato, cucumber, or melon plants affected with bacterial wilt or mosaic should be pulled and left in place. If they are very small they can be removed without allowing them to rub against the remaining healthy plants.

Pruning and Training Tomatoes.—Tomatoes are usually pruned and trained to single stems by removing the side branches as soon as they appear. They may be supported by stakes (see Fig. 7) or by strings. The strings may be tied to the base of the tomato plant or tied to wires stretched at the bases of the plants. The tops of the strings and stakes are secured to wires stretched above the rows. The plants should be tied to the strings or stakes by means of jute twine or raffia, in order to prevent the weight of the vine and fruit from pulling the plant downward. In making the knot ample room should be provided for the growth in diameter of the stem.

Vine Crops.—The cucumber and melon vines are supported by strings and stakes as are tomatoes. The pruning of the vine crops is slightly different. The laterals are allowed to grow until the first female flower appears, and then the tender growing point is broken off at the first leaf beyond the first female flower, leaving the leaf intact. If this pruning operation is delayed the yields will be greatly reduced.

Pruning at Transplanting Time.—At transplanting time care should be used to avoid all unnecessary pruning of the above and below ground parts. This statement applies to all vegetables. The use of clay pots in growing plants eliminates much pruning, especially of roots.

Ground Beds or Raised Benches

Most vegetable growers make use of ground beds because of the economy of space and lower original cost. Raised benches can, however, be used for vegetable production. Crops can be set more conveniently in raised beds or benches and they mature more quickly as a rule.

The soil in ground beds can be prepared with labor saving devices such as plows, disks, and harrows drawn by horse or tractor power (see frontispiece). The soil in raised benches, on the other hand, must be prepared by hand methods. Economy of labor must be given due consideration, because the cost of labor is one of the chief items of production expense.

Fig. 9. An excellent crop of spring cucumbers. The plants are vigorous, disease and insect free, and are maturing a heavy load of high grade fruits.

Varieties of Vegetables for Forcing

The vegetables forced are as a rule limited to a few varieties. Preference for varieties varies in different localities, and the market preference, together with disease resistance, quality, and ability to produce under forcing conditions, should influence the choice of variety. The better forcing varieties which produce well under Ohio conditions are listed on following page.

Table 3.—Varieties of Vegetables Best Suited for Forcing in Ohio

Vegetable	Fall and Winter	Spring
Asparagus	Mary Washington	Mary Washington
Beans	Burpees Stringless Green Pod	Burpees Stringless Green Pod
Beets	Crosby Egytian	New Century, Detroit Dark Red
Carrots	Coreless, Nantes, French Forcing	Coreless, Nantes, French Forcing
Cauliflower	Early Snowball	Early Snowball
Celery		Golden Plume
Cucumber	Cleveland Hothouse, Vickory, Davis Perfect, Geneva (new seedless variety), Abundance	Abundance, Cleveland Hothouse, Deltus, Davis Perfect, Geneva
Dandelion	Thickleaved	Thickleaved
Lettuce	Grand Rapids Forcing, Eberle's Ohio Strain	Philip's Strain, Grand Rapids Forcing
Mint	Peppermint	Peppermint
Muskmelon	Emerald Gem, Extra Early Knight Gold Champlain, Rocky Ford Hearts of Gold	Emerald Gem, Extra Early Knight, Gold Champlain, Rocky Ford, Hearts of Gold
Mustard	Southern Giant Curled, Fordhook Fancy	Fordhook Fancy, Southern Giant Curled
New Zealand Spinach	New Zealand	New Zealand
Parsley	Champion Moss Curled	Champion Moss Curled
Radishes	Scarlet Globe, Cincinnati Market White Icicle	Scarlet Globe, Cincinnati Market, White Icicle
Rhubarb	Victoria	Victoria
Spinach	Victoria, King of Denmark, Viroflay	Victoria, King of Denmark, Viroflay
Tomatoes	Globe, Marhio (purple), Marglobe	Marhio, Globe, Early Detroit, Bonny Best, Marglobe
Water Cress	Upland	Upland
Chicory	Witloof	Witloof

Disease and Insect Control

Disease and insect pests in greenhouses can often be held in check by proper sanitary methods, some of which have already been suggested. Rotations of warm and cool season crops, namely, crops that require 60° F. and 50° F. night temperatures, are a great aid in controlling both insect and disease pests. Red spiders and white flies rarely prove troublesome on crops grown at the lower temperature. Tomato Fusarium (wilt) can be held in check by keeping the soil temperature at or below 70° F. Verticillium wilt, on the other hand, is favored by cool temperatures. Insects and diseases are frequently harbored by flowering plants in vegetable greenhouses.

The control of greenhouse pests other than those referred to on the following pages is about the same as for outdoor insects. The reader is referred to Ohio Extension Bulletin 76, "Control of Garden Insects and Diseases," for this information.

Seed Treatment to Control Diseases

Corrosive Sublimate Solution.—Diseased plants should never be set in greenhouse soil, and cauliflower, cucumber, muskmelon, and tomato seed should be treated before it is planted. Corrosive sublimate is usually used for seed treatment. It may be purchased in tablet form of all drug stores. Directions for making the solution are given on the bottle in which the tablets are sold. Cucumber and muskmelon seed is treated ten minutes and cauliflower seed for eighteen minutes with a 1 to 1000 solution, and tomato seed is treated in a 1 to 3000 solution for five minutes. Solutions made from the powdered corrosive sublimate may be used if more than four or five pounds of seed are treated. One ounce of the powdered corrosive sublimate in eight gallons of water makes a 1 to 1000 solution.

All seed should be washed in clear, running water for a few minutes after the treatment, allowed to dry, and then planted. Be careful not to reinoculate the seed after treatment by placing it in contact with untreated packages which were formerly used around the seed.

Hot Water Treatment.—The treatment of cauliflower seed is more effective if hot water at a temperature of 122° F. is used for 18 minutes rather than corrosive sublimate. If the hot water treatment is used it is essential that the temperature be held exactly at the designated point.

Soil Sterilization as a Means of Control

Many diseases and insect pests can be completely or partially controlled by steam soil sterilization. Nematodes, centipedes and millipedes, Rhizoctonia, Sclerotima (often referred to as lettuce drop), Fusarium, Pythium (damping off), cut worms, grubs, and sow bugs are

Fig. 10. An exceptionally good crop of fall-grown tomatoes. Note good set and freedom from leaf mold.

among the pests that can be controlled by steam. When soil is sterilized every effort should be made to sterilize units as a whole—that is, sterilize each ground bed or greenhouse at one time, in order to reduce the dangers of recontamination.

Soil Filled Flats.—Soil in flats can be sterilized in an apparatus especially designed for the purpose, or in discarded dairy pasteurizing outfits, canning retorts, or similar second hand equipment. Treatment for one to two hours without pressure is ample for the sterilization of the flats.

Ground Beds.—Steam liberated through tile lines is the most effective means of sterilizing soil in ground beds. The tile lines are usually laid 12 to 16 inches deep and from 16 to 24 inches apart. A volume of steam is more important than high pressure. It may be necessary to turn the steam into the tile lines for 10 to 15 hours in order to raise and hold the temperature at the desired point for the proper length of time. Several hours at 200° F. is ample, but six to eight hours at 180° F. is necessary for the control of several more resistant pests.

Effect of Sterilization on Soil Content.—Soil sterilization makes nitrogen and phosphorus more available and consequently usually makes soils temporarily more fertile. It also increases the soluble salt content of the soil and may therefore make a few very productive soils less productive. The treatment for soluble salt toxicity has already been described.

Fumigation to Control Pests

Several pests in greenhouses can also be controlled by fumigation. Aphids and thrips can be controlled by fumigation with nicotine preparations. The directions for the use of these preparations come with each purchase. Aphids and white flies can also be controlled by fumigation with hydrocyanic acid gas. Directions for its use are included with each purchase.

Much care must be used to avoid burning injury if cyanides are used. Many of the common recommended dosages are too strong for vegetables, especially if they are growing on ground beds. Calcium cyanide should not be used stronger than one ounce per 7000 cubic feet of greenhouse space until experience has proved that stronger dosages are not harmful. Well hardened plants are able to withstand much stronger dosages than succulent plants. Hydrocyanic acid gas must not be used when the plants are covered with a copper fungicide. Cyanides are extremely poisonous and should be used with great care. Houses should always be posted with warning signs when the gas is used. Fumigations should always be carried on at night and the temperature should not be allowed to drop during the process, as the gas will be absorbed by the moisture which condenses on the foliage and burning may result.

Control Spray for Red Spiders

A glue spray made by dissolving one pound of glue in ten gallons of water is very effective for the control of red spiders. The glue should be dissolved in one or two gallons of boiling water and then diluted. If the plants are syringed a week later the glue will again become softened and kill additional spiders.

Greenhouse products bring a high price only if they are better than the same products secured from other sources. Every precaution should, therefore, be taken to grow perfect vegetables by utilizing all available modern cultural practices.

After the high quality produce is grown it is equally important to grade and pack the uniform produce in attractive packages. The grades for most vegetables have been standardized by the United States Government, and many of the packages which can be used for marketing vegetables have also recently been standardized. The grades established by the government may

Fig. 11. Grading and packing greenhouse grown tomatoes by disinterested parties for a greenhouse growers association at Berea. A more uniform grade is insured by the use of one packing agency for all growers. (*Photograph courtesy H. B. Ward*)

need slight modification before they are entirely suitable for greenhouse products.

The grades established by the government can be secured from the Ohio Division of Markets at Columbus, and the information concerning legal packages can be secured from the Bureau of Agricultural Economics (Service and Regulatory Announcements No. 116), United States Department of Agriculture, Washington, D. C.

Ohio hothouse tomatoes are usually packed in 8-quart baskets; cucumbers are packed in barrels, baskets, and cartons; leaf lettuce is packed in baskets and barrels; and spinach, radishes, and miscellaneous forced vegetables are packed in any of the previously mentioned containers. The trend is toward substantial, cheap yet attractive, small gift packages. Paper cartons are also being used more extensively.

The growers in all important greenhouse centers are organized. In all sections an attempt is made to sell the vegetables on a graded basis and to use uniform packages. The grades and packages vary considerably throughout the different sections of the state. This variation is due in a large degree to the different varieties (especially cucumbers) used in the different sections. One of the next steps which should be taken in the state is that of securing a state wide organization so that a more orderly marketing plan can be perfected. This will involve the use of standard varieties.

The method of securing a uniform pack varies with the local type of organization. In most instances the individual grower is responsible for the grade. If his grade fails to meet the requirements set up by the association officials he is warned and finally excluded from the association if he fails to comply with the grade specifications. (Applied to only one association.) In a few instances the vegetables are graded and packed by disinterested parties at central packing houses. This latter method has great merit, especially if the growers are located near each other.

In most cases supplies are purchased through the association. Advice is also given concerning the proper time to harvest the crops and how much to harvest. The present trend is that of growing several crops rather than one crop. Tomatoes, cucumbers, and miscellaneous crops are being grown more and more, while lettuce is being grown on a less extensive scale. One of the most important problems confronting the industry is that of producing profitable fall and winter crops to take the place of leaf lettuce. This is largely a cultural or management problem.

The methods of managing the cooperative associations are somewhat different in the different sections. In spite of this they all accomplish approximately the same purposes. In one section all members sell all their produce through one sales agency. In other sections each individual can sell to one or more customers, provided, of course, that each is charged the association price. Each method accomplishes the same result, but the former method is less likely to be subject to misunderstandings which often cause price slicing and lack of harmony.

MORE hothouse vegetables are grown in Ohio than in any other state in the union. Approximately 600 acres of grass representing an investment of over $25,000,000 yield an annual return of more than $7,000,000.

Most of the greenhouse plants are located near Ashtabula, Akron, Cincinnati, Cleveland, Columbus, Dayton, Newark, Toledo, and Youngstown. This industry represents the highest type of intensive agricultural production. The products from this industry are of the highest quality and nutritional value.

Bulletins for Vegetable Growers

Extension Bulletins and Circulars

Extension Bulletin 86, Potato Growing in Ohio
Extension Bulletin 76, Control of Garden Insects and Diseases
Extension Bulletin 75, Mexican Bean Beetle
Extension Bulletin 103, Growing Vegetable Plants
Extension Bulletin 109, Rhubarb Culture
Extension Bulletin 114, Tomatoes for Canning
Ohio Farm Gardens
Fertilizers for Vegetable Crops
Correspondence Courses

The bulletins and circulars mentioned above and prepared especially for Ohio growers may be had by writing to the Publications Department, College of Agriculture, the Ohio State University, Columbus, Ohio.

The following bulletins may be secured from the Ohio Agricultural Experiment Station, Wooster, Ohio.

Ohio Experiment Station Bulletins

Bulletin 408, Chemical Fertilizers for Greenhouse Lettuce
Bulletin 447, Paper Mulch for the Vegetable Garden
Bulletin 399, Relation of Weather to the Dates of Planting Potatoes in Northern Ohio
Bulletin 430, The Normal Multiple Sprouting of Potatoes
Bulletin 432, Ohio Potato Diseases
Bulletin 420, Fertilizers for Early Cabbage, Tomatoes, Cucumbers, and Sweet Corn
Bulletin 433, Farmers Produce Markets in Ohio

The College of Agriculture and the Experiment Station are your institutions. Call on them when wanting help.